DOE/MC/30056 -- 5045
(DE96000576)

Utilization of Lightweight Materials Made From Coal Gasification Slags

Quarterly Report
March - May 1995

June 1995

Work Performed Under Contract No.: DE-FC21-94MC30056

For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
Morgantown, West Virginia

By
Praxis Engineers, Inc.
Milpitas, California

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1.0 PROJECT OBJECTIVES, SCOPE AND DESCRIPTION OF TASKS

1.1 Introduction

Integrated-gasification combined-cycle (IGCC) technology is an emerging technology that utilizes coal for power generation and production of chemical feedstocks. However, this process generates large amounts of solid waste, consisting of vitrified ash (slag) along with some unconverted carbon, which is disposed of as solid waste. In previous projects, Praxis investigated the utilization of "as-generated" slags for a wide variety of applications in road construction, cement and concrete production, agricultural applications, and as a landfill material. From these studies, we found that it would be extremely difficult for "as-generated" slag to find large-scale acceptance in the marketplace even at no cost because the materials it could replace were abundantly available at very low cost. It became apparent that a more promising approach would be to develop a variety of value-added products from slag that meet specific industry requirements. This approach was made feasible by the discovery that slag could be made into a lightweight material by controlled heating in a kiln at temperatures between 1400 and 1700°F. These results indicated the potential for using such materials as substitutes for conventional lightweight aggregates (LWA). The technology to produce lightweight and ultra-lightweight aggregates (ULWA) from slag was subsequently developed by Praxis with funding from the Electric Power Research Institute (EPRI), Illinois Clean Coal Institute (ICCI), and internal resources.

The major objectives of the subject project, funded by DOE's Morgantown Energy Technology Center (METC), are to demonstrate the technical and economic viability of commercial production of LWA and ULWA from slag and to test the suitability of these aggregates for various applications. The project goals are to be accomplished in two phases, each of 15 months duration. Phase I, which includes the production of LWA and ULWA from slag at the large pilot-scale, is due for completion on 14 December 1995. The scheduled completion date of Phase II, which involves commercial utilization of these aggregates in a number of applications, is 14 March 1997.

1.2 Scope of Work

The project scope consists of collecting a large sample of slag (primary slag) which will be processed for char removal and then subjected to thermal or pyroprocessing to produce expanded slag aggregates of various size gradations and unit weights, ranging from 12 to 50 lb/ft^3. A second slag sample will be used for confirmatory testing. Technical data generated during the production and testing of the products will be used to assess the overall technical viability of expanded slag production. The expanded slag aggregates will then be tested for their suitability in manufacturing precast concrete products (e.g., masonry blocks and roof tiles) and insulating concrete, first at the laboratory scale and subsequently in commercial manufacturing plants. These products will be evaluated using ASTM and industry test methods.

In addition, a market assessment will be made based on an evaluation of both expanded slag aggregates and final products, and market prices for these products will be established. In order to assess the economic viability of these utilization technologies, relevant cost data for physical and pyroprocessing of slag to produce expanded slag aggregates will be gathered for comparison with (i) the management and disposal costs for slag or similar wastes and (ii) production costs for the conventional materials the slag aggregates would replace. This will form the basis for an overall economic evaluation of expanded slag utilization technologies.

1.3 Task Description

A summary of the tasks to be performed in Phase I is given below:

Task 1.1 **Laboratory and Economic Analysis Plan Development**: Development of a detailed work plan for Phase I and an outline of the Phase II work.

Task 1.2 **Production of Lightweight Aggregates from Slag**: Selection and procurement of project slag samples, slag size preparation including char removal, and slag expansion in direct- and indirect-fired furnaces. Preliminary laboratory-scale studies will be conducted before bulk samples of expanded slag are collected for processing. The char recovered from the slag preparation operation will be evaluated for use as a kiln fuel and gasifier feed. Environmental data will also be collected during preparation and expansion of slag.

Task 1.3 **Data Analysis of Slag Preparation and Expansion**: Analysis and interpretation of project data, including development of material and energy balances for slag processing and product evaluation.

Task 1.4 **Economic Analysis of Expanded Slag Production**: Economic analysis of the utilization of expanded slag by determining production costs for slag-based LWAs and ULWAs. An estimated market value will be established for the various expanded slag products. Expanded slag production costs will be compared with the costs of disposal and management of slag as a solid waste.

Task 1.5 **Topical and Other Reports**: Preparation and delivery of topical, financial status, and technical progress reports in accordance with the Statement of Work.

The Phase II effort will focus on field studies conducted on expanded slag aggregates to test their performance as substitutes for conventional materials in various applications, including masonry blocks, roof tiles, insulating concrete, and insulation fill. Mix designs will be formulated and tested by refining the material proportions used in previous work. Commercial manufacturing practices, standards, and equipment will be used for this work. New applications may also be identified during the course of this work. The economic analyses conducted in Phase I will be further refined in Phase II using the new data.

1.4 Scope of this Document

This is the third quarterly report and summarizes the work undertaken during the performance period between 1 March 1995 and 30 May 1995.

2.0 SUMMARY OF WORK DONE DURING THIS REPORTING PERIOD

2.1 Summary of Accomplishments

The following was accomplished during the current reporting period:

1. Following discussions with their operations engineers, a formal understanding was reached with a gasifier operator confirming their participation and support to the project. This includes obtaining a large sample of slag from them to serve as the primary project slag. They have requested that they be identified only as the primary slag supplier at this time.

2. Arrangements were made to collect 20 tons (80 drums) of the primary slag. Also, four drums of the secondary slag sample generated from an Illinois coal, which was collected earlier from TVA's National Fertilizer Development Corporation (NFDC) gasification facility, were shipped from reserve storage to Fuller Company for production of LWAs.

3. The primary sample was received at Penn State where characterization and planning for char removal were initiated.

4. Laboratory evaluation of expansive clay as a binder for fine slag to produce large aggregates and its potential for blending with slag for kiln processing were completed.

2.2 Chronological Listing of Significant Events

The following significant events occurred during the current reporting period:

Date	Description
03/05/1995	Decision made regarding the primary and secondary project slags
04/04/1995	Letter confirming participation by a gasifier operator received
04/15/1995	Laboratory extrusion testing of the advance sample using an expansive clay binder completed at Fuller
05/09/1995	Secondary slag sample shipped from storage to Fuller for testing
05/21/1995	Primary slag sample received at Penn State
05/30/1995	Characterization and processing for char removal started

3.0 TO DATE ACCOMPLISHMENTS

This section documents the work completed to date in the first three quarters of the project:

Date	Accomplishments
10/24/1994	"Draft Laboratory and Economic Analysis Plan" prepared and submitted
11/07/1994	Advance slag sample collected from an operating gasifier and sent to Penn State University
11/18/1994	Tabling operation on advance sample successfully completed and prepared slag sent to Fuller and Silbrico for expansion
12/02/1994	Final "Laboratory and Economic Analysis Plan" prepared and submitted
12/14/1994	Testing of advance slag sample at Fuller and Silbrico indicates that it has excellent expansion properties
02/15/1994	Analysis of clay and slag to evaluate blending initiated at Fuller
03/05/1995	Decision made regarding primary and secondary project slag samples
04/15/1995	Laboratory extrusion testing of the advance sample using an expansive clay binder completed at Fuller
05/21/1995	Primary slag sample received at Penn State for preparation
05/30/1995	Characterization and analysis of primary slag initiated; completed particle size distribution and ash analysis of two drums of sample

4.0 TECHNICAL PROGRESS REPORT

4.1 Slag Sample Selection and Procurement

In the previous quarter, testing was conducted to determine the expansion characteristics of an advance sample of slag obtained from an operating gasifier using a bituminous coal feed in order to determine whether it could be considered as the project primary slag sample. The slag sample demonstrated excellent expansion characteristics and it was selected as the primary sample. In this quarter, a formal understanding was reached with the personnel of a gasification facility confirming their participation and support to the project. This included obtaining a large sample of slag from them to serve as the primary project slag. They have requested that at this time they be identified only as the source of the primary slag sample. Arrangements were made to collect 20 tons (80 drums) of the primary slag sample based on a sampling and homogenization procedure provided by Praxis. Ten drums were kept at the site as a reserve sample and the remaining 70 drums were shipped to Penn State for char removal and size preparation.

Four drums of another slag sample generated from an Illinois coal feed which had been collected earlier from TVA's NFDC gasification facility were shipped to Fuller Co. This sample will serve as the secondary project slag.

4.2 Slag Preparation for Char Removal and Characterization

Seventy drums of the primary slag sample were received at Penn State. Two drums were selected randomly and sampled to check the size distribution and carbon content. The results are given in Table 1.

Table 1: Size Consist of Two Drums of Primary Slag Sample

	Drum 1			Drum 2		
Size	**Direct Wt%**	**Ash %**	**Cum Wt%**	**Direct Wt%**	**Ash**	**Cum Wt%**
+6M	4.3	100.8	4.3	4.3	101.1	4.3
6 x 8M	9.4	101.0	13.7	5.1	101.1	9.4
8 x 12M	21.3	100.8	35.0	21.7	101.1	31.1
12 x 16M	10.9	100.2	45.9	12.8	100.7	43.9
16 x 20M	6.5	98.3	52.4	7.5	99.9	51.4
20 x 28M	5.4	83.4	57.8	5.5	90.5	56.9
28 x 35M	5.7	56.9	63.5	5.4	47.6	62.3
35 x 48M	10.2	47.7	73.7	9.9	57.8	72.2
48 x 65M	8.8	51.8	82.5	8.5	56.8	80.7
65 x 100M	6.8	65.9	89.3	7.1	69.6	87.8
-100M	10.7	98.3	100	12.2	94.9	100
Total	100	84.78		100	86.44	

The particle size analysis of the two drums is within the range of deviation for samples collected previously by Praxis. However, the sample will be further homogenized during the size preparation and char recovery step.

As may be seen in Table 1, the +20 mesh sample is essentially char-free and the minus 100-mesh slag contains only 2-5% char, which indicates that the char content occurs in the intermediate size fraction of 20-100 mesh. These results will help in selecting screen sizes before and after the char removal step.

4.3 Laboratory Evaluation of Slag and Clay Blends

Work completed earlier on the advance slag sample confirmed that it could be expanded in a controlled manner to produce expanded lightweight products with unit weights ranging between 22 and 64 lb/ft^3. In this quarter, expansion testing of the fines was conducted to make extruded pellets using an expansive clay as a binder and to determine whether expansive clay can be blended with slag prior to expansion. Based on these results and observations, the slag was selected as the primary slag for the project. In this quarter, laboratory expansion of slag fines was initiated to evaluate the following issues related to commercial utilization of slag:

- The feasibility of producing coarse aggregates from slag fines
- The potential for blending slag fines with an expansible clay.

For these studies, expansive clay was selected for use as a binder since it can participate in the expansion process, is abundantly available at low cost, and offers the following advantages:

- Good binding capability
- Good expansion characteristics, expanding in the same temperature range as slag
- Located close to the commercial gasifier where the slag is generated and expanded.

Based on these criteria, a clay was selected from a commercial lightweight aggregate plant in Alabama. The actual source will be disclosed once their participation in the project is formally secured. The slag size selected for this work was 48 mesh, based on previous experience, and the clay size was 20 mesh. Mixtures of slag and clay starting at 50/50 and proceeding with reducing proportions of clay were tested in a 2" bench-scale extruder. Extrusion with slag-to-clay ratios of 50/50, 60/40, and 70/30 was successful. The product containing the lowest proportion of clay was made with extremely high energy draw and attempts to extrude an 80/20 mixture failed completely. The extrusion test indicated that a high-plastic clay is ideal for mixing with the minus 48-mesh slag. It was also noted higher proportions of slag in the mix made the material somewhat abrasive, causing notable wear in the barrel of the bench-scale extruder.

Moisture requirements prior to extrusion of each mix were determined as follows:

- 50/50 21.40%
- 60/40 12.15%
- 70/30 11.36%

The three extruded mixture products were fired in an electric muffle furnace to allow visual inspection of the product at 1800°F, 1900°F, and 2000°F after a 15-minute preheat at 1000°F on each sample fired. The results are illustrated in Figure 1, which consists of photographs that show the products from pyroprocessing of 3/8"-diameter extruded pellets.

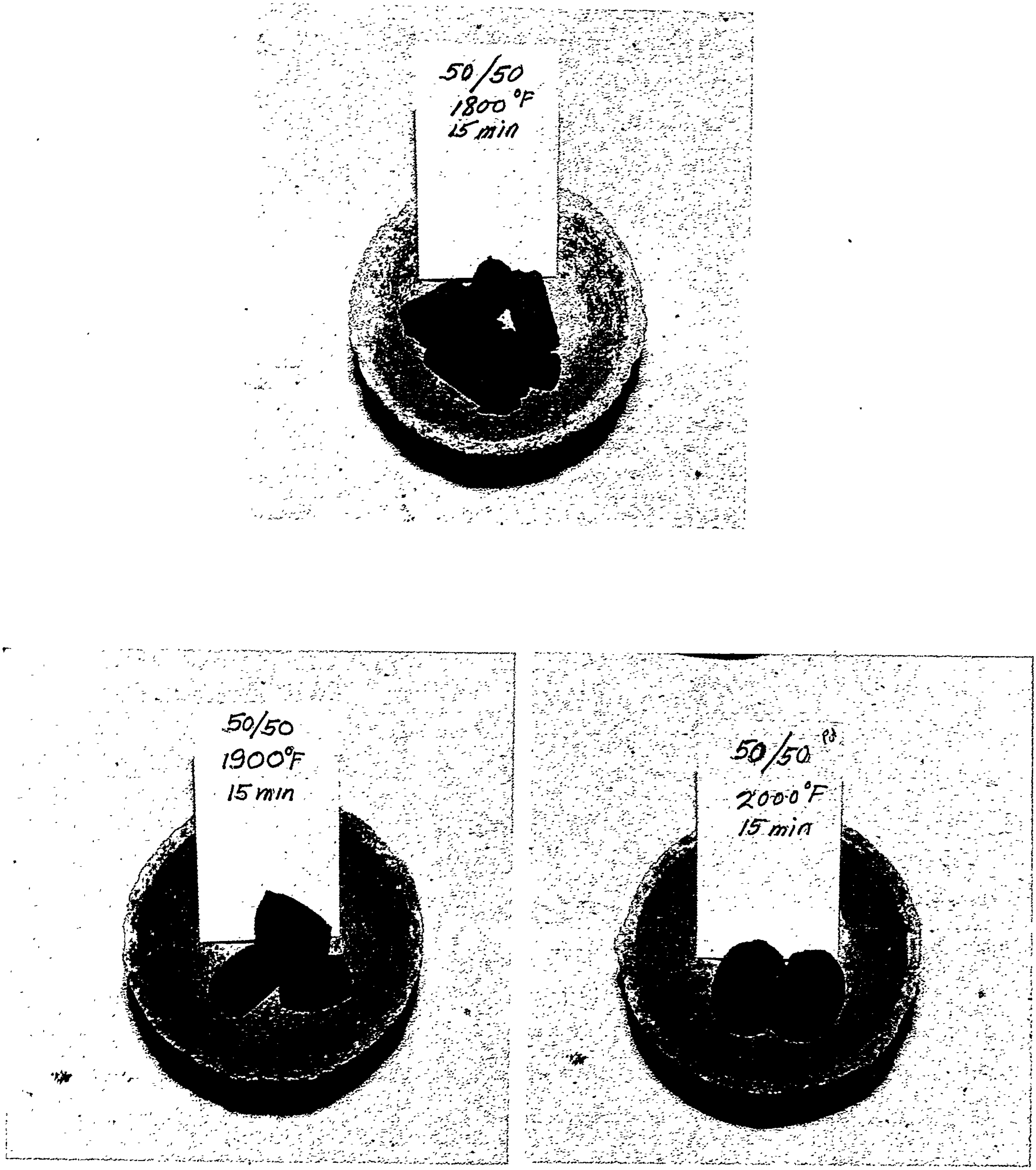

Figure 1. Expanded Products Using 50/50 Slag/Clay Mixture

These results show that all mixes expanded extremely well with uniform internal structure, with the best results being achieved at 1900°F and 2000°F. There were no signs of fusion or stickiness, as was expected based on the chemistry study reported in Quarterly Report No. 1.

Due to the limited amount of slag material available, which limits our capability to produce a large number of pellets for each mix, a full burn series was conducted using the 50/50 mixture. The results obtained are as follows:

▸ Extrusion moisture	21.4%
▸ Dry unit weight (unburnt 3/8" diam. pellets)	52.5 lb/ft^3
▸ Preheat 15 minutes @ 1000°F	
▸ Fire 15 minutes @ 1900°F	
▸ Product unit weight	29.16 lb/ft^3
▸ Volume expansion	1.3 to 1

4.4 Conclusions and Recommendations

Based on the reported results, the following recommendations can be made:

- Two drums of the primary sample were analyzed for size distribution and char content. The +20 mesh fraction of the samples contained no char. The minus 100-mesh fraction contained 2-5% char. These data will help finalize the char separation flowsheet.

- The minus 48-mesh fraction of slag could be combined with a known expandable plastic clay. As with the clay obtained from an operating kiln for bench-scale testing, a quality structural-grade product is anticipated based on visual inspection of the internal pore structure. With size reduction after expansion, this product could also possibly be made into a block aggregate.

- Extruded pellets made from slag/clay blends expanded at 1900°F, which is higher than the expansion temperature of slag but lower than that of clay alone.

- The extruded feed can be produced with a clay content as low as 30%. However, some wear in the extruder barrel may result from using slag/clay mixes containing more than 50% clay. This could be a maintenance cost to the process.

- Use of higher proportions of slag resulted in lower pellet moisture, which would have a major effect on overall process fuel consumption requirements, with greater use of slag lowering fuel costs.

- There was no indication of any fusion or stickiness with all extruded mixtures fired up to 2000°F.

5.0 PLAN FOR THE NEXT QUARTER

The following activities are planned for the next quarter:

- Laboratory-scale expansion testing of the second slag sample blended with an expansive clay binder to produce coarse aggregates
- Preparation of the primary slag sample for char removal
- Material balance calculations for each slag based on the results of advance sample processing
- Work on the economic analysis will be initiated; the costs of producing lighweight aggregates from slag and disposing of solid wastes (slag) from the gasification facility will be determined.